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INTEGRATION OF LCA CONSTRUCTION IN STRAW AS INSULATION MATERIALS FOR BUILDING WALLS

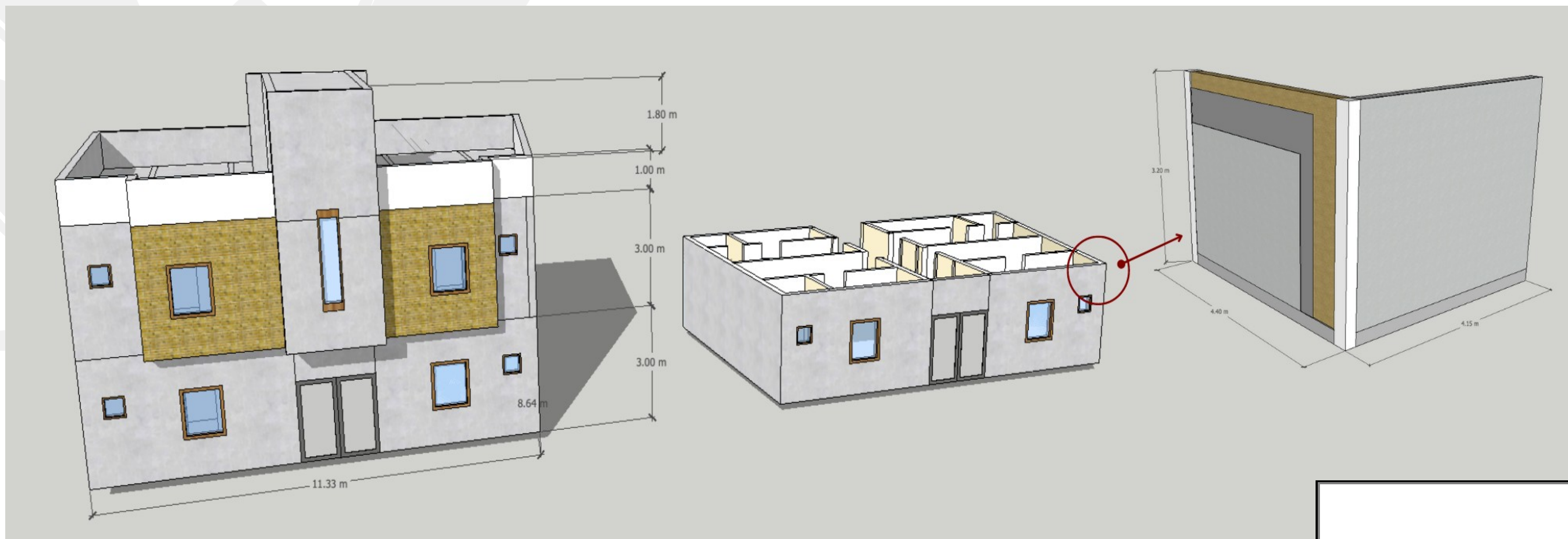


Introduction and Problem Statement

Energy crisis and global warming have been one of the major issues that the world is facing as of today. Buildings account for majority of total energy consumption. Thermal insulation can improve energy efficiency; however, conventional materials are non-renewable resource that contribute to GHG emissions.

This calls for exploration for materials such as straws as insulation materials. In the Philippine context, production of rice and corn is abundant in the country. This offers excellent opportunities as these resources can be used as alternatives given its properties.





Objectives of the Study

01.

To analyze the environmental impact of using straw material as an insulation material on walls

02.

To examine the different properties that straw insulation possess

03.

To compare the different types of agricultural waste such as wheat, corn, and rice husk as materials for straw insulation

04.

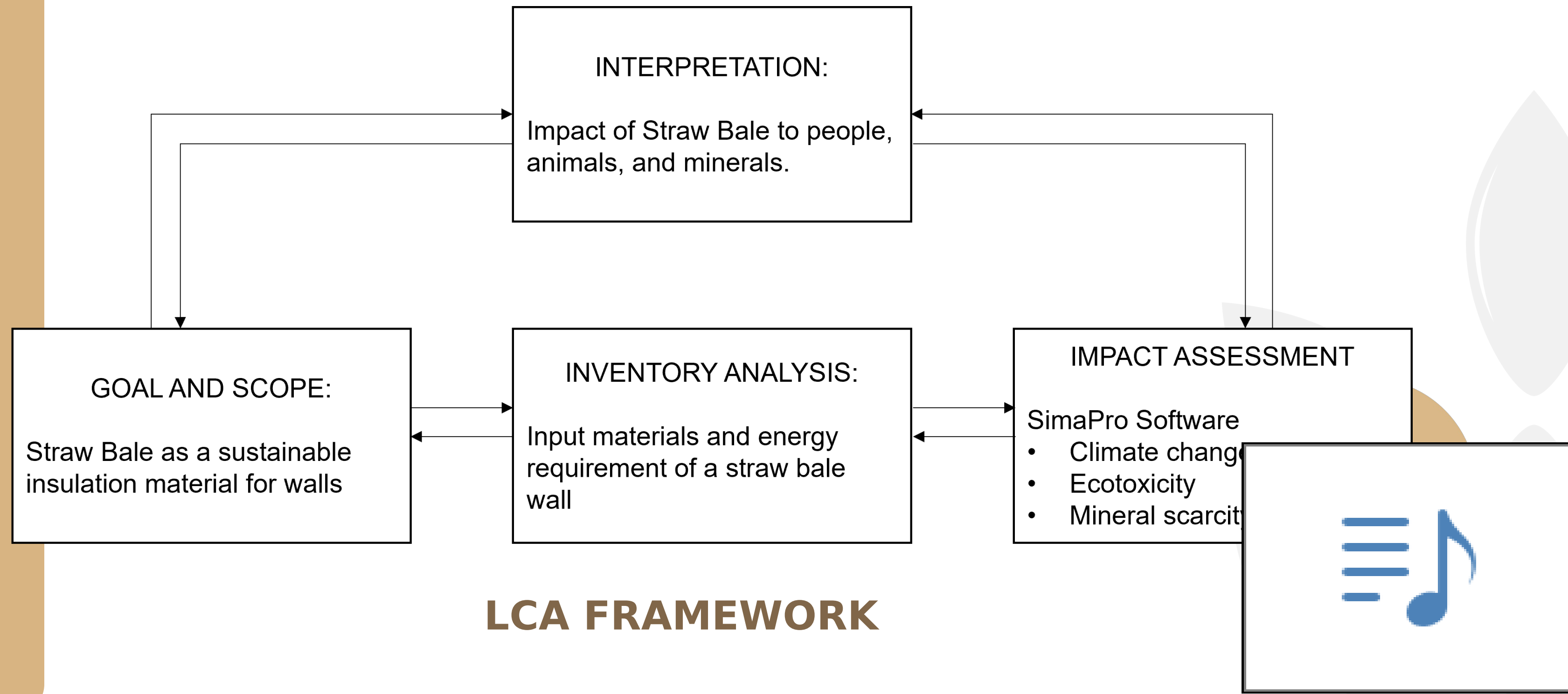
To identify which agricultural waste can be best used for straw insulation in the Philippines

05.

To compare straw bale wall from concrete hollow block CHB wall



METHODOLOGY: LIFE CYCLE ASSESSMENT



METHODOLOGY:

SIMAPRO ANALYSIS

Item	Element	Amount	Unit Metric
Straw Bales	Straw	40.54	kg
	Polypropylene	0.05	kg
Wooden Frame	Wood	11.58	kg
	Steel	0.91	kg
Interior Plaster Earth	Clay	0.96	kg
	Silt	0.60	kg
	Sand	0.84	kg
	Water	1.44	kg
Exterior Plaster Earth	Clay	0.48	kg
	Silt	0.30	kg
	Sand	0.42	kg
	Water	0.72	kg
Lime Plaster	Natural Hydraulic Lime	0.25	kg
	Sand	0.75	kg
	Water	0.37	kg
Coating	Premixed (Natural Hydraulic Lime and River Sand)	0.21	kg
	Water	0.06	kg
Wall Assembly	Water	0.02	m ³

Materials contained in 1 sq.m straw bales wall

Item	Element	Amount	Unit Metric
Straw Bales	Diesel fuel for baling	0.12	kg
	Straw bales transport by tractor	0.20	tkm
Wooden Frame	Wood transport by truck	9.85	tkm
	Steel transport by road	0.005	tkm
Plasters	Hydraulic lime transport by truck	0.41	tkm
	Sand transport by truck	0.03	tkm
Wall Assembly	Electricity	0.96	kWh

Energy Requirement in 1 sq.m straw bales wall.



METHODOLOGY:

SIMAPRO ANALYSIS

METHOD LCA ANALYSIS:

LC-IMPACT | marginal pref. | all
imp. | 100y

REFERENCE:

D'Alessandro, F., Bianchi, F., Baldinelli, G., Rotili, A., & Schiavoni, S. (2017). Straw bale constructions: Laboratory, in field and numerical assessment of energy and environmental performance. *Journal of Building Engineering*, 11(1). 56-68. <https://doi.org/10.1016/j.jobbe.2017.03.012>

Item	Element	Amount	Unit Metric
CHB	CHB	234.50	kg
Mortar Mix (Class C)	Sand	71.78	kg
	Cement	15.76	kg
Plaster Mix (Class C)	Sand	39.60	kg
	Cement	8.64	kg
Steel (10 db mm)	Steel	2.016	kg

Materials contained in 1 sq.m CHB Wall





Nebraska / Load-Bearing
Wall Style

STRAW BALE WALL

CONSTRUCTION TECHNIQUE

Nebraska / Load-Bearing Wall Style -

Straw bales are attached to the foundation and piled up until its roof framing. With this, the weight of the roof would be endured by the straw bale.

Post and Beam Method - has a frame to help support the loads. The frame can be made from steel, wood, and concrete blocks. In this way, the straw bale would only bear its own self-weight.



Post and Beam
Method



Straw Bale Plaster

Lime Based Plaster

- Commonly used as it provides breathability and durability in the structure, and it is low maintenance.
- Low maintenance - avoids cracking of the wall leaving it a longer duration of a smooth wall.

Clay/Earth Based Plaster

- Clay plaster holds more moisture compared to straw, resulting in the clay plaster to absorb the moisture and release it
- Prevent the straw bale from absorbing the moisture, prolonging its good condition.



Straw Bale Houses



BaleHaus Located in
the University of Bath, England



Non-Load Bearing Straw Bale Walls in Minamiboso and Toyama City, Japan



Straw Bale Structure in
Thailand

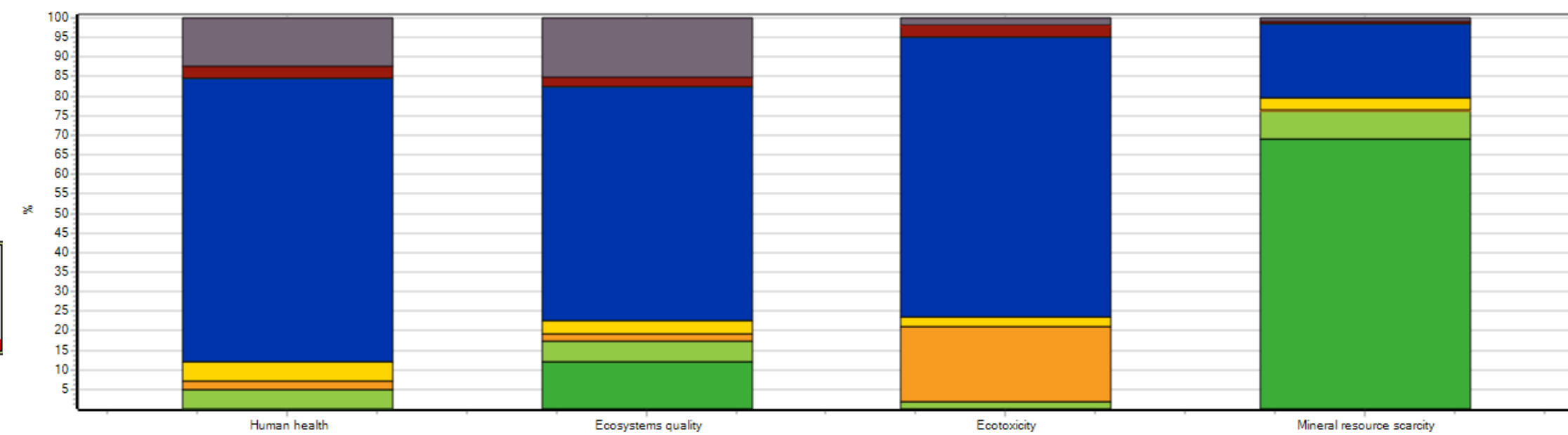
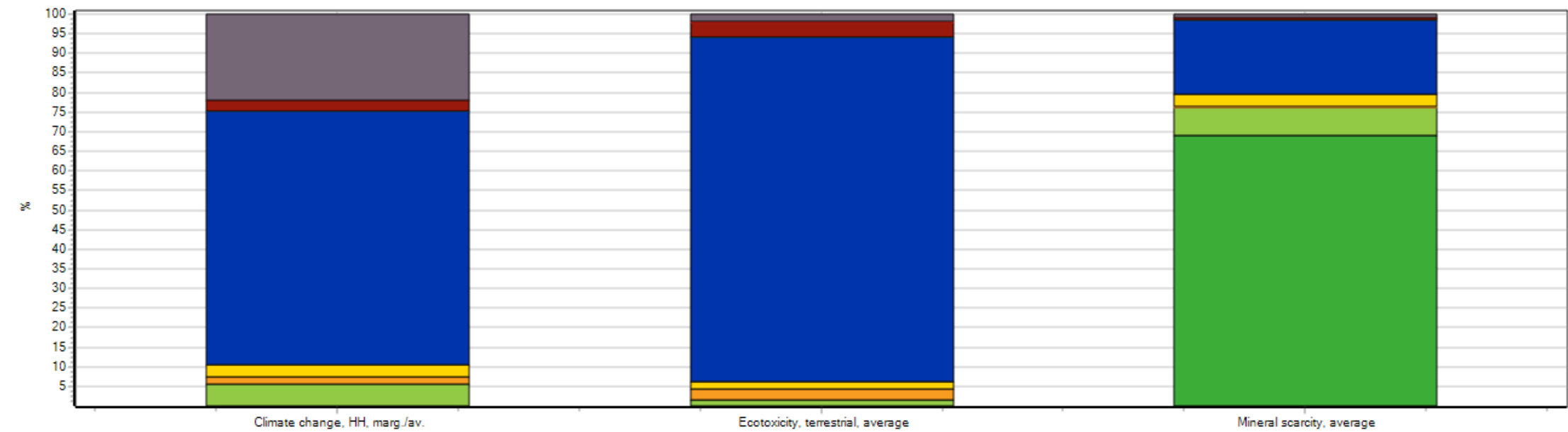
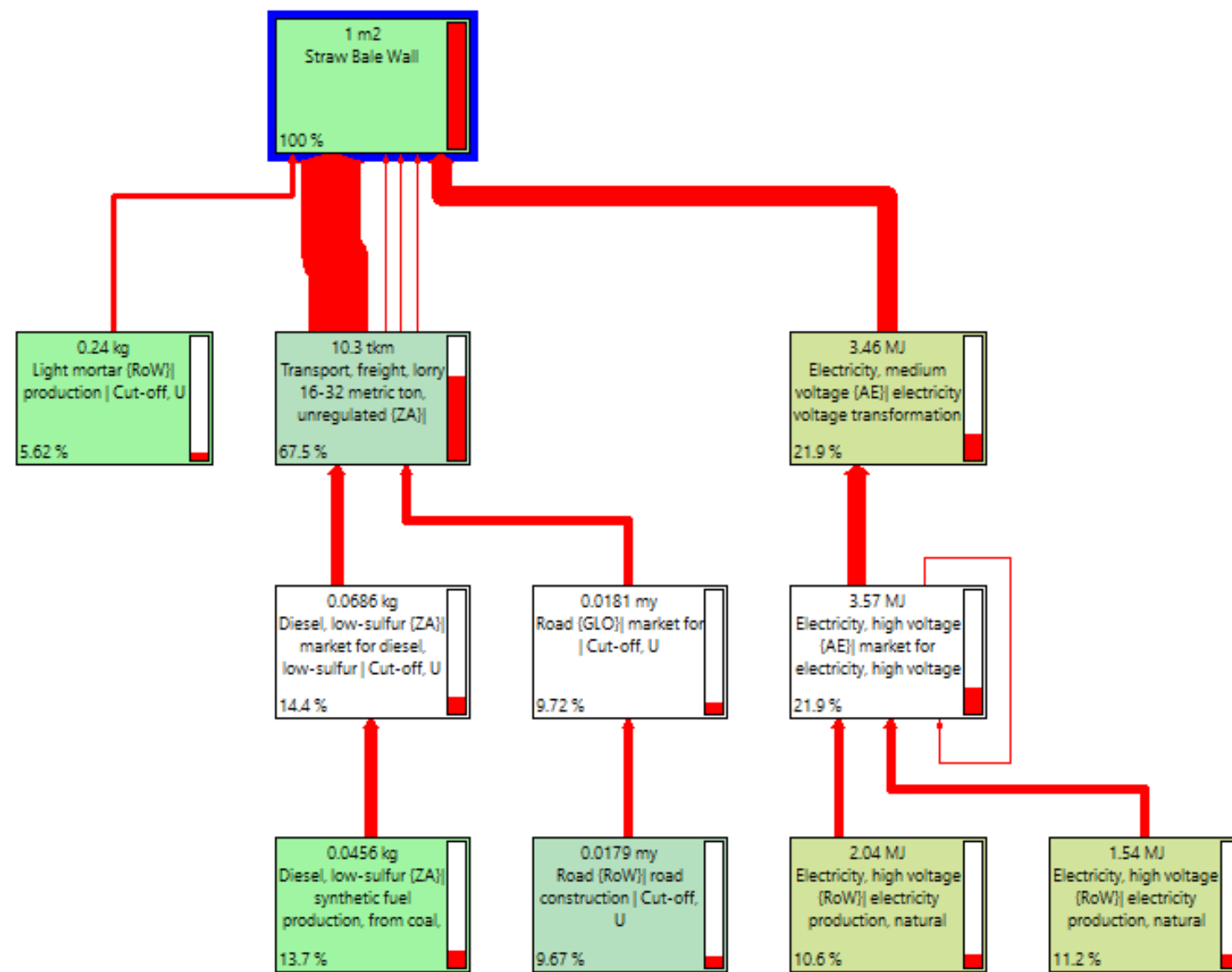
Straw Bale Houses



**Bacolod City, inside of the University of Negros Occidental - Recoletos,
known as Earth Chapel**



Life Cycle Assessment



LCA INTERPRETATION

Impact Assessment



Transport

- 2.4% to 5.5% of CO₂ emissions come from construction transport.
- transportation impact would be low if locally available straw bales were utilized (Gonzales. 2014)

Electricity

- utilization of straw bales has reduced the number of bricks by 2/3 (World Habitat, 2018)
- there is an increase in soil conservation and a decrease in the usage of the firing fuel.

Mineral Resources

- the use of straw bale in houses can save about 15% of wood.
- reduces construction waste and is biodegradable reusable

LCA INTERPRETATION

Damage Assessment



Human Health

- Utilization of straw bale decreases air and waste pollution
- It is crucial to consider how a material may affect the workers

Mineral Scarcity

- straw bale wall provides a sustainable alternative in construction as opposed to conventional materials
- replaces components such as cement, steel, and wood for load

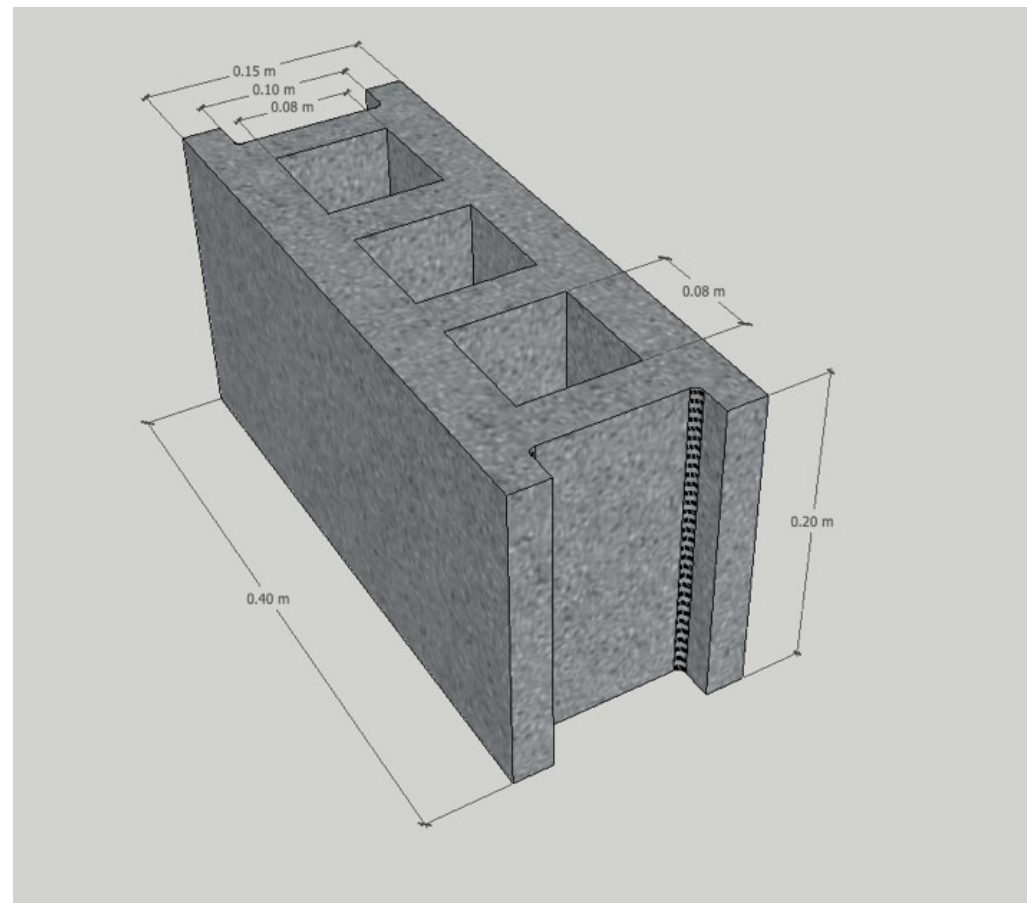
Ecosystem

- Utilization of straw bale decreases air and waste pollution
- Beneficial to biodiversity

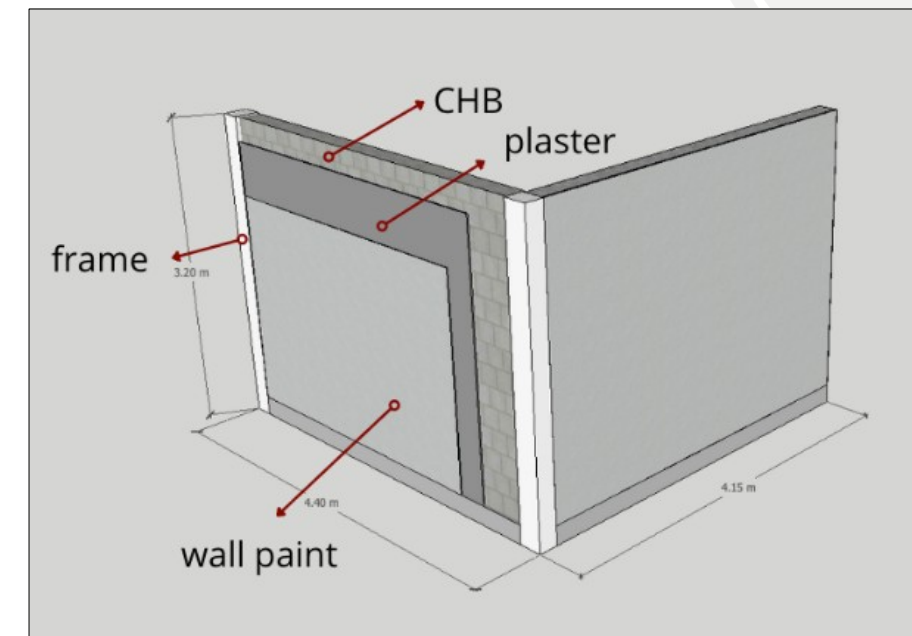
Concrete Hollow Blocks (CHB)



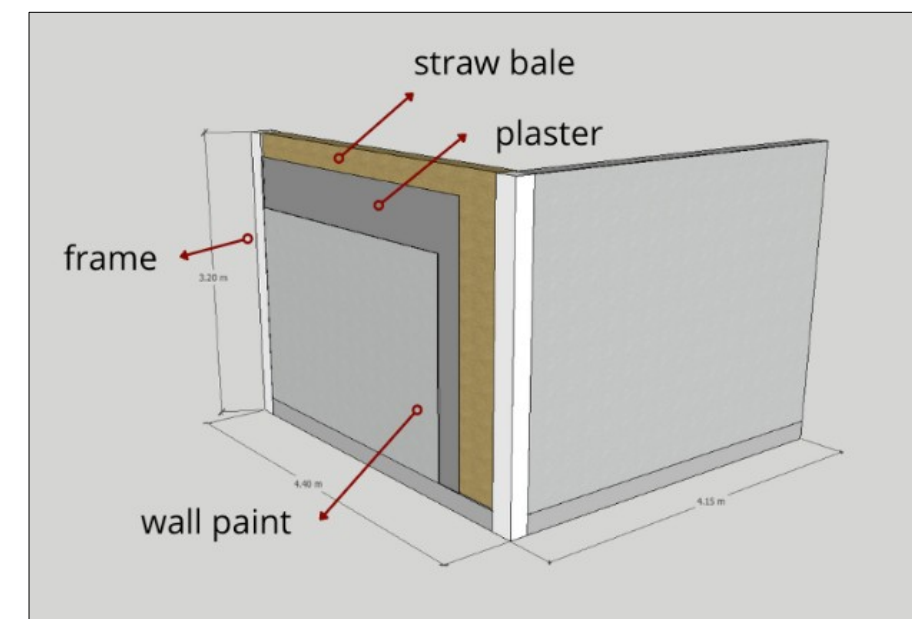
Most used type of material in the Philippines (residential structures)



Calls for other alternative materials that are **environmentally friendly**

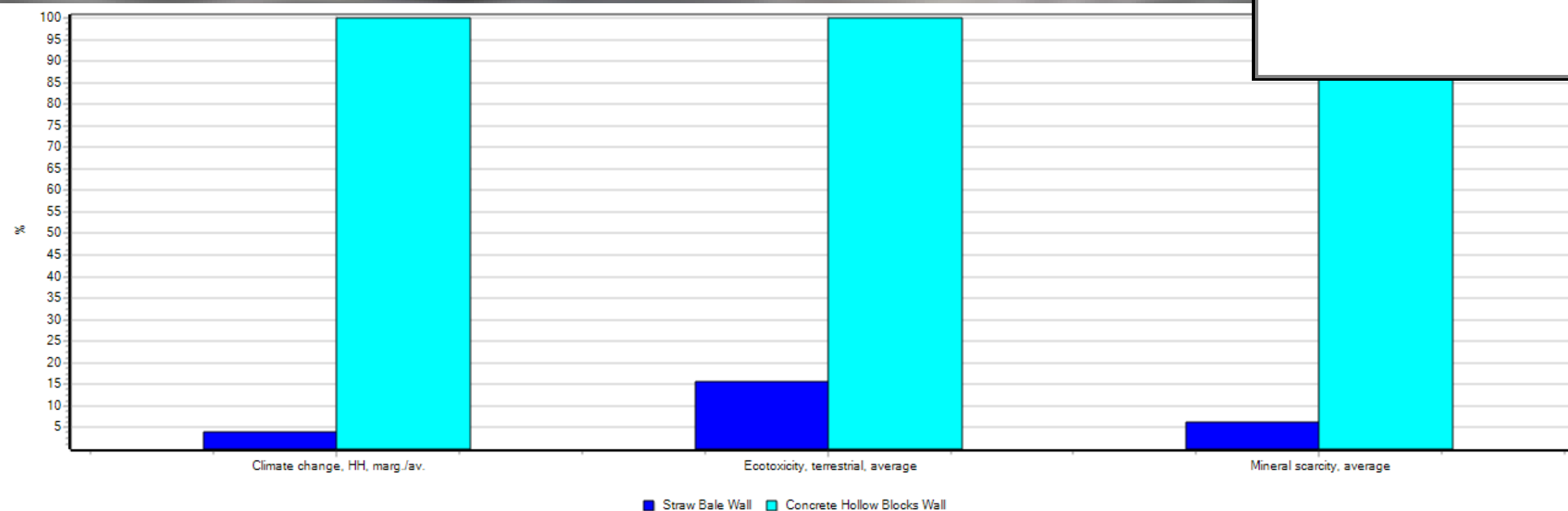
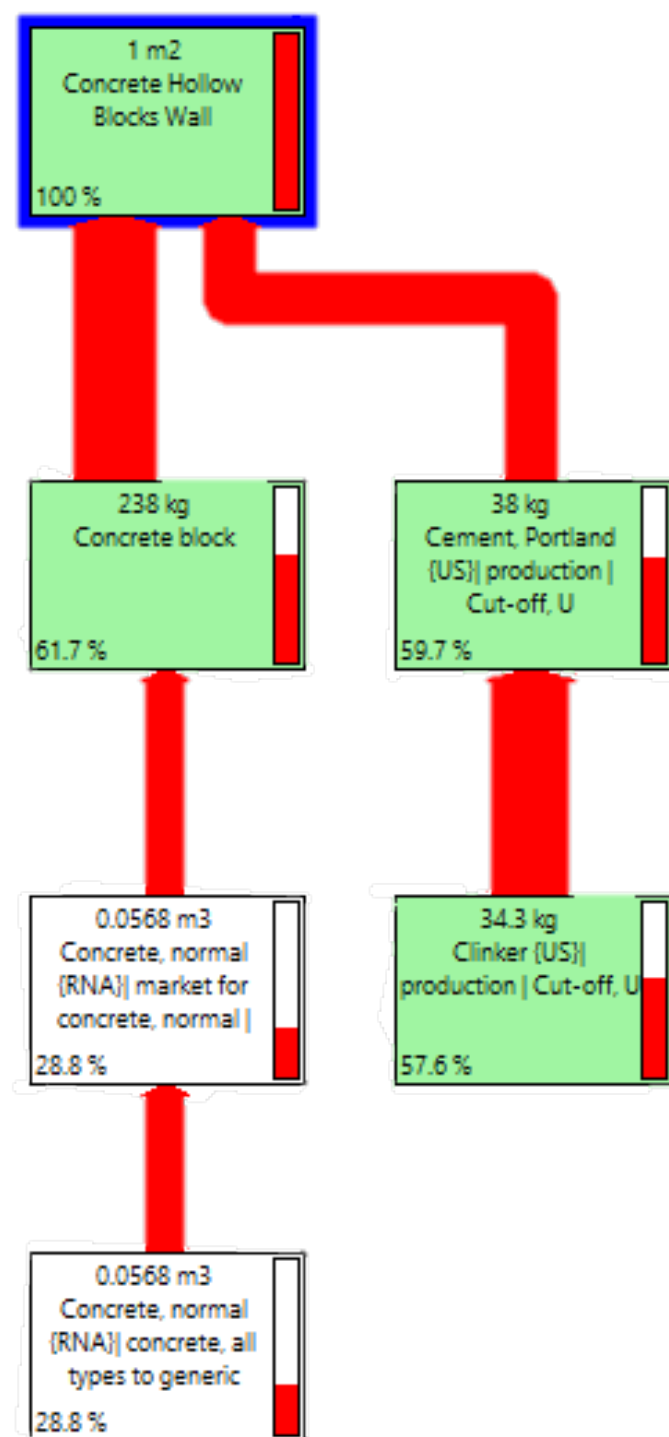


CHB Wall

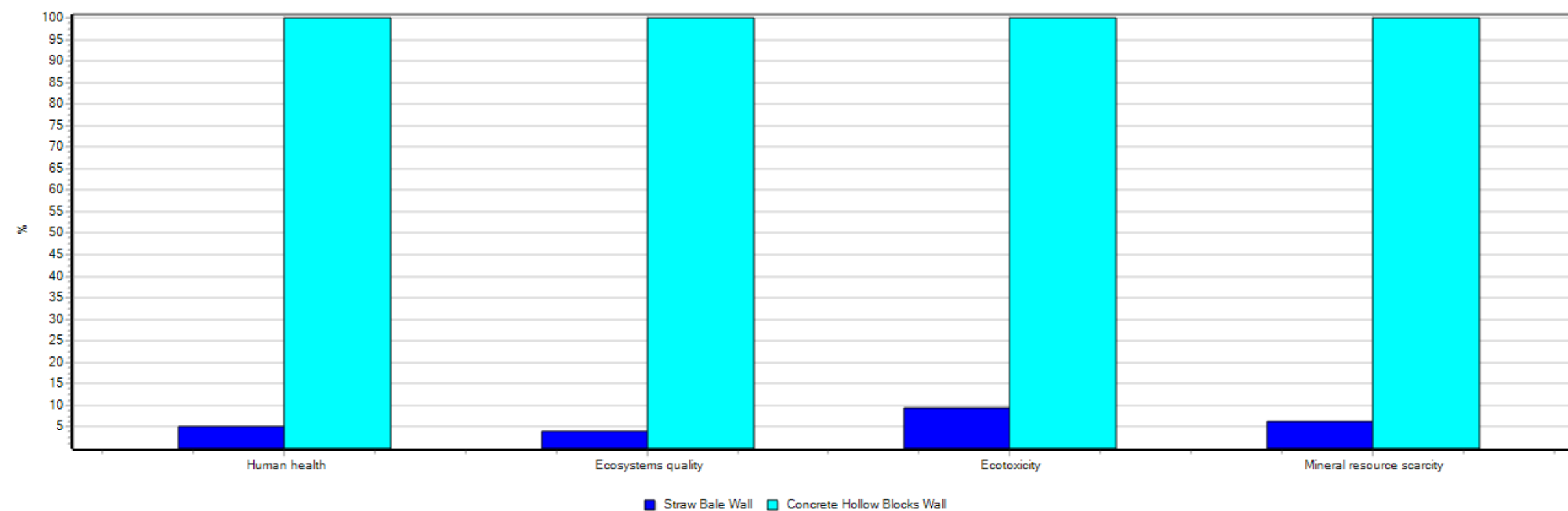


Straw Bale Wall

Life Cycle Assessment



Method: LC-IMPACT | marginal pref. | all imp. | 100y V1.00 / Characterization / Excluding long-term emissions
Comparing 1 m² 'Straw Bale Wall' with 1 m² 'Concrete Hollow Blocks Wall';



Method: LC-IMPACT | marginal pref. | all imp. | 100y V1.00 / Damage assessment / Excluding long-term emissions
Comparing 1 m² 'Straw Bale Wall' with 1 m² 'Concrete Hollow Blocks Wall';

Comparison of CHB and Straw Bale



Number Required Per 1m ² of wall	Thermal Conductivity (W/(m·K))	Thermal Transmittance (W/(m·K))	Embodied energy (MJ/m ²)	Global Warming Potential (kgCO ₂ -eq/m ²)
11 concrete blocks	0.64	3.2	169	9.6
3 straw bales	0.07	0.16	28	2.5
3 half straw bales	0.07	0.32	14	1.3

Low Values of
Primary Energy and
Global Warming Potential

Straw Bales
Promising insulating
material due to its
thermal conductivity

(González, 2014)

Cost Analysis: CHB and Straw Bale



Cost Analysis for 1 m ² CHB wall	
Element	Price (PhP)
CHB	241.375
Sand	96.66
Cement	159.82
Steel (RSB)	80.64
Total	PhP <u>497.86</u>

Cost Analysis (Php/m ²)			
Element	Low Estimate	Mid Estimate	High Estimate
Straw	364.86	364.86	364.86
Wood	308.51	369.16	429.82
Steel	36.40	36.40	36.40
Lime Mortar	124.97	124.97	124.97
Sand	2.22	2.22	2.22
Silt	0.25	0.25	0.25
Polypropylene	4.39	4.54	4.69
Total	841.61	902.41	963.22
Ratio to CHB cost	<u>1.69</u>	1.81	1.93



Properties of Straw

as an Insulation Material



01

Thermal Insulation

Thermal conductivity varying from 0.03 W/(mK) to 0.1 W/(mK)
Straw type, Bale density, Temperature and Relative Humidity
High fiber content and large fibers would lower thermal conductivity values

02

Moisture

Affected by the environment; Water vapor resistance associated with density
Fiber content, nature of fiber, size, thickness and porosity
Different types have no effect on moisture absorption

03

Mechanical

Ductile (no breakage)
Type and source of straw, fiber sizes
Plastering improves load-bearing capacity



04

Durability

Withstand forces
Increasing the thickness of insulator or plaster
Plastering increases durability

05

Fire Resistance

Primary concern is fire safety
Flammability of loose straws
Plastering improves fire resistance in comparison to an unplastered straw bale wall



Comparison of Different Types of Agricultural Waste as an Insulation Material

Results and Discussion

01

Rice husks – best in

PH
Best used for straw insulation in the Philippines is the rice husks. Rice is used frequently here. Moreover, PH is tropical.

02

Mineral & Transportation

Mineral resource scarcity (read as material scarcity) is the greatest concern in creation. Transportation is also a great concern.

03

Corn husk feasibility

Foreign facing infrastructure might be made more efficient (in some cases) than methods that look at acquiring from local resources.

04

Simapro Greatest

Simapro results say that straw bale wall is the greatest contributor to mineral scarcity. Transportation becomes a factor as initiatives are made to reduce climate change impact.



Conclusion



01

Most Eco-Friendly

The rice husk straw bale wall is the most eco-friendly. However, every other wall is promising alternative than a CHB wall.

02

Straw bale vs CHB: Cost

Straw bale walls are between 69% to 93% more expensive than CHB walls, enough to stop mass adoption of straw bale walls.

03

CHB Prevalence

If the CHB walls are as harmful as Simapro results claim, straw bale walls should have been used in more projects.

04

Higher Price Rationale

Reason for a higher price for the materials for a straw bale wall is because of lack of market for straw bale increasing its price value, especially in urban areas.

Recommendation

01

Different straw bale walls

A comparative analysis should be done further: an investigation between the different types of agricultural waste as an insulation material.

02

LCA comparison between them would have been more beneficial to settle their differences

Study the reduction of the price of straw bale walls

The higher price on a straw bale wall is because of lack of market for it, especially in urban areas.

Hence, it is recommended to further analyze the market for the materials in the Philippines to create a more economical pricing for it.





THANK YOU
FOR LISTENING!

